

THE NEUROMAGNETIC BRAIN ACTIVATION PATTERNS OF INDUCED
COMPASSION IN ADVANCED ZEN MEDITATION PRACTITIONERS

by

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ABSTRACT

The concept of compassion is complex, where religious and philosophical writings are abundant but scientific publications remain sparse. The surge in neuroscientific publications related to prosocial behaviors, spirituality, and Buddhist-based meditation practices has sparked a growing interest in issues once considered foreign to the scientific arena. There is currently a strong need to develop neuroscientific methods that incorporate subjective trait and state measures. In addition, the use of powerful new technologies such as high density whole head magnetoencephalography (MEG) provides novel methods for mapping brain states over time in a way never before thought possible. The current proposal will attempt to use MEG in combination with both state and trait scales to better understand how mind and brain are related to the production of induced compassion. The sample for investigation will include high level Zen Buddhist practitioners with many years of intensive religious practice within a Buddhist framework that requires the cultivation of compassion. The hope is that these findings may one day shed light on an array of psychiatric disorders where certain forms of social impairments could benefit from practices traditionally sequestered within only religious contexts.

Dedicated to all those who have suffered at the hands of those who have chosen hate as their mode of being, may grace come to victim and perpetrator alike, and may the ignorance of hate one day fully give way to compassionate embrace.

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CHAPTER I

REVIEW OF THE LITERATURE

Introduction

The concept of compassion as a natural outcome and goal of spiritual practice is inherent to all of the world's major religions (Barasch, 2009). Whether viewed as a kind of intelligence in its own right, or as a facet of both intrapersonal and emotional intelligences, the cultivation of compassion can be considered a learning process proceeding through stages of contemplative religious practices.

Definitions of Compassion

The common definition of compassion regardless of religious or spiritual tradition is “the ability to perceive the pain of another and the inclination to act to alleviate that pain” (Lampert, 2005, p. vii). The components of this definition can be further elaborated. For example, the “ability to perceive” is the beginning step emerging from not only simple attention and awareness of what is happening in the other, but in addition requires the ability to place oneself within the shoes of the other, or to have empathy. This includes to actually experience to some degree what the other person is experiencing, and to then model what this means to that person, an ability commonly referred to as Theory of Mind (Goldman, 2006). The act to “alleviate” is usually related to love, a component inseparable from the “inclination” component where compassionate

love is "...a self giving, caring love that values the other highly and has the intention of giving full life to the other" (Fehr, Sprecher, & Gordon, 2008, p. 4). The necessity of including care in the notion of compassion is important, as the sharing of suffering is typically not sufficient for true compassion to occur (Donius, 1995).

A final component of compassion not captured in the above definition is the inclusion of the transcendent, or notion of mystical realization (unity experience) as an integrated component (Dalai Lama, Jordhen, Ganchenpa, & Russell, 2001). In the descriptions of compassion at this higher level, a nondiscriminatory theme emerges, i.e., the child molestor dying of HIV evokes the same level of compassion as the innocent child dying of HIV (Hopkins, 2001). The person's value stems not from cultural assignment of value but the apprehension of the person as actually being a higher spiritual power, or the deep realization, "One is expressed equally in each and every being, and so each is to be treated with compassion and care, not in any condescending fashion, but rather because each being, exactly as it is, is a perfect manifestation of Spirit." (Wilber, 1995, p. 327). The conclusion is echoed by Mother Teresa "I see God in every human being. When I wash the leper's wounds, I feel I am nursing the Lord Himself. Is it not a beautiful experience?" (Chaturvedi, 2005, p. 102).

A more complete and component based definition of compassion for comparison to both the meditation and neuroscientific literature is the following: Compassion is a process that includes; 1) Enhanced attentiveness to allow increased perception of another's emotional experience. 2) Modeling of the perceived emotional experience to feel or really understand what it is actually like to be the person having the experience

(empathy and Theory of Mind); 3) The generation of feelings related to unconditional love and caring concern towards the one experiencing the suffering resulting in the motivation to relieve the suffering; 4) The apprehension that all living beings are equal manifestations of a higher spiritual power, where no difference between oneself and others exists.

The most prevalent religious literature describing the cultivation of compassion is found within both modern and historical Tibetan Buddhist literature where Mahayana Buddhist texts serve as the foundational driving force (Williams, 1989). This philosophical view is present not only in the more commonly written about Tibetan practices (Hopkins, 2001), but also those found within traditional Zen Buddhism that shares Mahayana Buddhist texts as a foundational source (B. Suzuki, 1959). In Zen, the ultimate level of mystical unity, enlightenment, or nondual realization is sought through both sitting meditation practice, and more rapid dialogue based methods. The process is typically concurrent with, or follows methods to integrate the experience into the real world of ordinary experience thus leading to *karuna*, the Japanese term for compassion (D. Suzuki, 1960). The study of advanced Zen practitioners hence represents a unique population where compassion cultivation is always expected as an outcome of long term Zen Buddhist practice. The proposed study will attempt to identify neurophysiological correlates of compassion in advanced formally sanctioned Zen Buddhist practitioners, most known as *Roshis* or *Senseis*, who are required by their spiritual tradition to embody compassion within the process of their spiritual attainment.

Cognitive Neuroscience of Meditation and Compassion

While the use of brain and physiological recording devices to scientifically study meditation has extended well over half a century, it has only been in the last decade that newer and more sophisticated neuroimaging methodologies have ushered in an explosive and unprecedented interest in the neuroscientific basis of meditation practices (Walsh & Shapiro, 2006). The resulting new information has brought increased acceptance of meditation as a practice worthy of mainstream scientific investigation (Bhattacharjee, 2005) while opening the door to more systematic large scale investigations (Santa Barbara Institute for Consciousness Studies, 2005).

Methodological Challenges

Although scientific curiosity and acceptance has increased, a number of methodological challenges are noted. These include: 1) The generic use of the term meditation with few attempts to operationally define the term, or to implement validated measures with which to characterize meditation practitioners or their meditation states (Andresen & Forman, 2000; Jaseja, 2009); 2) The use of study designs with a disproportionate emphasis on acquiring state measures at the expense of trait measures (Cahn & Polich, 2006; Chiesa & Serretti, 2010); 3) A bias toward studying meditation practitioners with low amounts of training (Fell, Axmacher, & Haupt, 2010); 4) An overall research bias toward studies (nearly half) being done on Transcendental Meditation compared to the remaining studies that are divided across more than half a dozen other forms (see Appendix A); 5) A lack of methodologies that link what the actual subjective state or practice is during the “meditation” or stimulation period with

neurophysiological measurements (Josipovic, 2010; Shannahoff-Khalsa, 2003) . The problem is noted in the majority of neuroimaging studies, which fail to implement high quality study designs linking first person (introspective) data with third person (neurophysiological) data (Northoff & Heinzl, 2006).

While the cultivation of compassion appears to be one of two large poles at the core of nearly all the world's major religions, the scientific literature shows a relative dearth of compassion papers in terms of using either subjective or neurophysiological measures. The component of compassion is typically completely left out of meditation investigations. A small number of exceptions exist. There are three studies investigating the effects of compassion arising from meditation practice including: the degree of social connectedness coming from mindfulness meditation practice (Hutcherson, Seppala, & Gross, 2008); the effect of loving kindness states on back pain (Carson et al., 2005); and enhancing therapists intunement with their clients (McCollum & Gehart, 2010). These studies do not formally measure compassion but only assess aspects of it.

Neuroimaging of Compassion

EEG and Compassion

In the neuroscientific literature there are four studies directly measuring compassion in advanced meditators with one of these studies using EEG, and the remainder relying on functional MRI. The most relevant study measured eight long-term Tibetan Buddhist practitioners with 10,000-50,000 hours of meditation experience during compassion meditation using high density EEG (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004). The study demonstrated high levels of gamma activity (25-42 hz) in

predominantly frontal and parieto-temporal brain regions compared to controls. The amount of lifetime meditation was shown in addition to correlate with amount of lower level resting baseline gamma activity that was significantly different from the controls. The overall finding suggests that, in advanced Tibetan meditators, increased gamma band activity may result from longterm meditation practice and be highly amplified during compassion-based meditation. However, the study was limited in that the control group was nearly 30 years younger than the meditators on average and age differences for responses could not be ruled out.

A similar finding was reported in an analysis of a single long term advanced meditator (number of hours of practice were not given) where significant enhancement of gamma activity was noted in both visualization and self-dissolution meditation (Lehmann et al., 2001). A source localization using LORETA (low-resolution electromagnetic tomography) demonstrated that during visualization meditations there was more posterior (visual cortical areas) and right activation. In the case of dissolution of self there was greater gamma activation in the right superior frontal gyrus region. The later finding may have relevancy to the notion of higher level spiritual compassion where loss of self is said to naturally give rise to compassion. The shift to right sided activations may imply a quieting of the language dominant left hemisphere where autobiographical and conceptual representations of self are said to reside (Gallagher, 2000).

In one recent study Yoga practitioners engaged in a deep meditative yoga breathing technique demonstrated similar high amplitude gamma bursts. The study found that gamma band activity was localized in the middle temporal gyrus, with dominance on the

left. This finding differs from the studies mentioned above where frontal and right activations are more dominant but may reflect differences in meditation techniques (Vialatte, Bakardjian, Prasad, & Cichocki, 2009). The finding of less sustained bursts of more generalized gamma activity was reported in older studies (Banquet, 1973; Kasamatsu & Hirai, 1966; West, 1979) where precise computer analysis methods for localization were not available. Therefore gamma band activity while not frequently reported in the meditation literature is a finding noted throughout the literature and across different meditation methods.

The significance of gamma band activation during meditation remains unknown. The measurement of gamma is now recognized as a valid, phenomenon observable across a large array of EEG and MEG perceptual, sensory, and memory tasks (Herrmann, Frund, & Lenz, 2010). The enhancement in gamma frequency is thought to create a binding together of experience that leads to a holistic imprint of consciousness awareness (Cantero & Atienza, 2005). The significance of gamma in pathological states is also a focus of ongoing investigation where research over the last decade has pointed to a reduction or absence of gamma response in an array of disorders, particularly when using social and emotional processing triggers (Lenz, Fischer, Schadow, Bogerts, & Herrmann, 2010; Rippon, Brock, Brown, & Boucher, 2007). Hence gamma enhancement in meditation may reflect enhanced perceptual and attentional processing, including enhancement of internally generated emotional states such as compassion.

Functional MRI and Compassion

A functional MRI paper from Lutz, Brefczynski-Lewis, Johnstone and Davidson (2008) using moderately advanced Tibetan meditators demonstrated enhancements in brain regions responsible for empathy and mentalizing during human distress vocalizations. The regions with enhanced activation included the insula (most correlated with reported intensity of meditation), anterior cingulate, amygdala, and the right temporal-parietal junction (Lutz et al., 2008). A second functional MRI paper by Lutz, Greischar, Perlman and Davidson (2009) examined heart rate during the perception of human distress vocalizations as a function of amount of meditation practice. The heart rate was found to significantly increase during the compassion condition to a greater degree in the experts as compared to the controls. There was also reported strong right insula activation with more experienced practitioners showing greater dorsal anterior cingulate and partial left insula activation.

A study by Engstrom and Soderfeldt (2010) was done with a single advanced Tibetan meditator during compassion meditation using functional MRI. They demonstrated left frontal medial, cingulate, right caudate, and insula activations. Finally Pace (2009) measured cortisol and immune system functioning in response to stress in controls and long term meditators engaged in compassion meditation practice. The study did not demonstrate significant differences between groups, although there was a negative correlation between amount of meditation experience and in the parameters used to gauge the stress response.

Compassion Trait Measures

What all of the above studies have in common is a lack of any standardized assessment related to the trait of compassion or the state of compassion. The studies make the assumption that because practitioners were advanced Tibetan meditators, or received training in compassion based practices, they therefore automatically had achieved a compassion state or enhancement in this trait. A reason for excluding metrics related to compassion may be the lack of any standardized measure with good psychometric properties to measure compassion. An exhaustive search of the literature found only one specific measure developed as part of a doctoral dissertation to measure care and compassion in nurses (Donius, 1995). Although the developed measure demonstrated good internal and external validity, it did not discriminate between groups where a differing level of compassion and caring ability would be hypothesized to exist (Donius, 1995).

Neuroimaging of Empathy

Since empathy is considered a required feature of compassion and much more widely studied, it is useful to review the literature for studies in which empathy was the primary focus of the research. Although there exist standardized measures of empathy with good psychometric properties (Spreng, McKinnon, Mar, & Levine, 2009; Yu & Kirk, 2009), only one empathy measure was identified as ever being used in a meditation study (Shapiro, Schwartz, & Bonner, 1998). The situation is improved within the functional MRI literature in which more than a dozen empathy based studies have been completed to date. The majority of the studies require participants to view others in pain,

and have demonstrated a large degree of overlap where systems directly modulating pain are seen to be activated during empathy (Decety, Hodges, & Van Lange, 2006). The brain regions most commonly involved demonstrate strong activations in the anterior cingulate (most strongly correlated with empathy) , anterior insula, and sensory-motor regions corresponding to the observed location of injury in the other (Decety, Harmon-Jones, & Winkielman, 2007).

In more recent work, where neuroimaging and lesion studies are reviewed, a double disassociation is noted. The two functionally different systems are: 1) A more cognitive system that appears to be involved in taking the perspective of the other, “as if” them, and involves the more frontal polar, and ventral medial areas, including portions of the anterior cingulate. 2) A more affective based system involving the inferior frontal gyrus (BA 44) in conjunction with congruent motor system activations (Shamay-Tsoory, Aharon-Peretz, & Perry, 2009). A region not mentioned in this paper but of notable significance in many empathy papers is the anterior insula (Singer & Lamm, 2009). This region appears across 162 studies of emotion to be the most consistently activated area (Kober et al., 2008). In comparing empathy studies with those relying more on states of love akin to compassionate states, the more medial insula seems to be activated compared to the anterior for empathy in pain observation studies (Singer & Lamm, 2009). In addition, there is a timing element in which the felt compassion for pain appears to occur later than the activations for the initial observation of pain (Immordino-Yang, McColl, Damasio, & Damasio, 2009). Hence, more medial anterior insular activations occurring later may correspond to an additional element of the more cognitive or perspective taking

system mentioned previously. This later finding shows some correspondence to maternal and unconditional love associated brain activations in the right insula, hypothalamic regions, orbitofrontal cortices (ventral medial regions) along with the periaqueductal gray (PAG) matter of the brain stem (Bartels & Zeki, 2004). An interesting finding is that the PAG is not activated in the passionate love condition but is activated in the maternal love condition (Bartels & Zeki, 2004). This dimension of unconditional love having unique neuroimaging markers was demonstrated in an fMRI study where participants viewed individuals with developmental disabilities (Beauregard, Courtemanche, Paquette, & St-Pierre, 2009). The results during unconditional love tasks showed middle insula, right basal ganglia, PAG, and the anterior cingulate as the areas with the most significant activation (Beauregard et al., 2009).

Although the findings are interesting and point to some uniqueness as well as considerable overlap in brain modules underlying empathy, love, and emotional states, there remain no studies examining sustained states that last more than 1-2 seconds owing to the limitations of MRI technology. Also, few EEG or MEG studies have attempted to understand another important component of compassion, which is love. Those studies done using EEG typically employ ERP using a loved one's face or associated word compared to a neutral stimulus. The studies in this case show an increase in brain potentials when viewing an image of a loved person, or hearing an associated word but no or limited information on possible generating sources is provided (Langeslag, Jansma, Franken, & Van Strien, 2007; Vico, Guerra, Robles, Vila, & Anllo-Vento, 2010). A study demonstrating more sustained electrical changes was conducted by Basar, Schmiedt-

Fehr, Oniz, and Basar-Eroglu (2008), who found increases in delta band activations in the frontal lobe when a person viewed a loved one compared to a neutral person. When examining empathy based EEG and MEG papers that are similar to those in the fMRI literature, there are three categories of findings: Those involving rhythm changes, a second involving event related potentials, and a third involving more global EEG trait patterns associated with empathy.

Those studies demonstrating EEG and MEG evidence of rhythm changes, commonly rely upon Mu rhythm changes in the sensori-motor systems (mirror neuron system) in the same regions representing the body area that is being affected by pain (Betti, Zappasodi, Rossini, Aglioti, & Tecchio, 2009; Perry & Bentin, 2009; Yang, Decety, Lee, Chen, & Cheng, 2009).

The second group of studies examines event related potential parameters where differences in amplitude are noted in pain versus non-pain stimuli sets but offer no or limited localization information (Decety, Yang, & Cheng, 2010; Fan & Han, 2008; Fukushima, Terasawa, & Umeda, 2010; Li & Han, 2010). One exception to this group of studies was conducted by Proverbio, Adorni, Zani, and Trestanu (2009) in which a contrast between suffering versus happy humans demonstrated using LORETA resulted in differences in the right occipital, hippocampal, left dorsolateral prefrontal cortex, and left amygdala with only women showing increases in right frontal areas of brain.

Finally, the last group used EEG as a trait pattern associated with the ability to have empathy. Light, Coan, Zahn-Waxler, Frye, Goldsmith, and Davidson (2009) and demonstrated more right frontopolar activation in children who scored high on empathy

measures. The finding is related to earlier reports that young children exposed to adverse environments who have less demonstrated empathetic ability had significantly less activation of the right frontal region (Jones, Field, & Davalos, 2000; Jones, Field, Davalos, & Hart, 2004).

Statement of Problem

Although a large number of studies has been conducted on traits associated with compassion these studies were done predominantly with MRI. This limits understanding to brief, 2-10 seconds epochs typical of MRI block designs that are further limited by restrictions of blood flow physiology (Logothetis, 2008). The small handful of studies conducted using electrical or magnetic activity recordings of the brain are, with the exception of the single study by Lutz (2004), all indirect measures of compassion measuring a facet, and with very limited spatial or temporal resolution that provides no or very limited localization values.

A number of questions remain unanswered within the scientific literature: 1) Is compassion as a final consequence of a presumably integrated meditation practice required of those in the highest form of Zen practice significantly enhanced? 2) Can MEG discern significant gamma band increases during subjective experiences of compassion in a way similar to what is reported in EEG during compassion based meditation? 3) Does EEG gamma band enhancement show a relationship to validated scales that capture dimensions of compassion? 4) Do scales developed to measure enhancements of traits associated with meditation and spirituality show significant

increases in Zen practitioners who are designated by the tradition itself to be high level or enlightened beings.

Significance of Study

The number of existing studies using advanced practitioners is difficult to estimate because of the vagueness of inclusion criteria. However, an informal survey of the scientific literature indicates likely less than 5% of studies have been conducted on advanced meditation practitioners. There are currently no known studies in the peer reviewed scientific literature on high level Zen practitioners who are of Western as opposed to Japanese descent and include a portion of “enlightened” individuals according to rigorous standards set forth by the official Japanese Soto Zen lineages in which they practice. The very specific form of Tibetan practices described above do not have any known corollary in Zen, and no studies have been conducted on Zen meditation practitioners to test for natural, or in a sense the “ordinary,” generation of compassion (Chiesa, 2009).

To address these limitations, the current project recruited a rare sample of advanced Zen meditation practitioners, many of whom have more than 20,000 hours of meditation practice, and are considered high ranking according to the stringent criteria of their religious order. The study extends the common definition of meditation beyond simple notions of enhanced awareness and/or relaxation response to include the often overlooked but implicit Buddhist notion of compassion. To validate level of meditation practice and outcome, unlike previous studies in the literature, a number of standardized measures will be used. Further, the study relies on the novel use of MEG technology in understanding

induced compassion. The use of MEG provides better spatial resolution than is possible with any prior EEG studies. The better spatial resolution helps to identify particular areas of the brain associated with states of compassion. The added advantage comes from acquiring information related to the neurophysiology of sustained (many minutes) as compared to a brief (1-2 second) MRI limited snapshots of brain activation reported previously.

Hypotheses

1. Zen practitioners compared to controls will demonstrate:
 - a) Increases on measures designed to capture mindfulness, general spirituality, mysticism, empathy, and depth of meditation.
 - b) Increases on state compassion measures during the real neuroimaging condition of compassion as compared to the fake control condition.
2. Zen practitioners compared to controls will demonstrate:
 - a) Neuromagnetic gamma/alpha ratio spectral band distributions with dominance in frontal and temporal brain regions.
 - b) Gamma/alpha ratio spectral band increases during a realistic human tragedy scenario as compared to a fake control condition.
 - c) Correlations between the gamma/alpha ratio spectral band difference score (real condition minus fake condition value) and the compassion composite difference score (subjective scale rating during the real condition minus the fake condition).
 - d) Correlations between the gamma/alpha spectral band difference score and spiritual trait measures.

CHAPTER II

METHOD

The proposed research is part of a larger exploratory investigation of neurophysiological correlates of highly advanced Zen meditators. However, the details of only those methods related to the research questions stated will be presented.

Subjects

A total of 20 healthy age- and sex-matched participants were recruited with equal numbers of males and females in each group of 10. Those participants with chronic psychiatric illness, neurological conditions, or other factors deemed likely to alter brain functioning were excluded. Participants ranged from 40 to 70 years, as this constitutes the most common age range of advanced meditation practitioners. Although there is a limited number of longitudinal studies on changes in structural and functional brain functioning over the life span, the available evidence suggests that most changes in cognitively matched subjects occurs between subjects younger than middle age and those at or higher than middle age (Brickman et al., 2005; Salat et al., 2004; Salat et al., 2005). There are few functional event related changes noted among those in the age range of 40-70 years (Daffner et al. 2006; Riis et al., 2009).

The untrained control subjects were screened for prior meditation exposure, and only those with minimal (lifetime informal meditation practice \leq 30 hours) or no meditation exposure were recruited. The recruitment was conducted through posters

placed on campus and at sanctioned surrounding community locations. The experienced participants were recruited from an official Soto Japanese Zendo (White Plum Asanga) that is inclusive of centers and temples in European countries. The subjects were all of Caucasian European descent. The advanced participants were selected according to multiple criteria: 1) They were ranked within an official Zen lineage. This implies they had met rigorous training objectives and met strict religious criteria indicative of deep spiritual insight. 2) An official Roshi recommended them at the time of recruitment as being spiritually accomplished according to his/her own oversight and intuitive understanding of the subject. Each participant had more than 10 years of interaction with an official Roshi.

Instrumentation

The state measures consisted of a previously standardized Meditation Depth Questionnaire (MDQ) and a small number of exploratory compassion state questions designed to be used during the neuroimaging compassion phase of the project. The compassion state questions were of two types: 1) A single direct self rating of overall subjectively experienced compassion 0-4 given after the subject completed the entire compassion task. The rating was completed while the subject was still in the scanner. 2) An indirect measure of compassion that presented the subject with 13 emotional categories including both positive and negative emotions given immediately after the presentation of each task component (real and fake control compassion condition) while the subject was still in the scanner. The rating scale was designed to emulate the Self Assessment Mannequin (SAM) used in a large body of previous emotional research

(Lang, Bradley, & Cuthbert, 1997) where each emotion is rated from 0-8 (see Appendix C). The goal of this second instrument was to embed two indirect core aspects of compassion identified as being the most common qualities of compassion indicated in the descriptive compassion literature into an array of less relevant emotional qualities. The two components selected for a compassion aggregate measure were “sadness” and “love”. This design was used for two reasons: 1) To decrease the risk of subject reporting bias where a subject may exaggerate their level of compassion to “look good” when rating themselves if they know they are being directly assessed. 2) To test for the possible contamination of compassion emotion by the concurrent experience of other negative emotions. This is important in any study of emotional research as emotions are not always isolated but can be a complex array of contradictory emotions. In the current study, it was speculated that the presented scenario could suffer the risk of not only inducing a compassion experience, but also making the subject angry if they thought about the perpetrators who hurt the person in the scenario, or they realized that they had been misled by the investigator during the control condition. Therefore, a second measure of, “anger” also was derived that included a combined the rating of “anger” and “spite” state self-ratings.

The trait measures were selected on the basis of their ability to capture the most critical dimensions of spiritual development through meditation practice. Only the total scores were used rather than subscales given the small sample size. The following previously standardized scales were employed: Functional-Assessment of Chronic Illness- Spiritual (FACIT-Sp-Ex) for general spiritual functioning, the Five Facet

Mindfulness Questionnaire (FFMQ) to capture predominantly changes in awareness and equanimity, the Balanced Emotional Empathy Scale (BEES), the Mysticism Scale (M-scale), and the Meditation Depth Questionnaire as a state measure (MDQ).

Self-Report Trait Scales

The Functional Assessment of Chronic Illness-Spiritual-Extended (FACT-Sp-Ex)

This is one component of a constellation of instruments originally developed to assess well-being and functioning in cancer patients (Webster, Cella, & Yost, 2003). While originally designed for this purpose, only a few questions make reference to actual illness with the majority of the questions making reference to general spiritual dimensions. The instrument has an advantage over many spiritual assessment instruments in that it does not tend to rely on specific religious terminology. It is appropriate for individuals from broad religious backgrounds. It asks subjects to rate their experiences over a 7-day time window and more readily assesses recent changes in well-being (Peterman, Fitchett, Brady, Hernandez, & Cella, 2002).

Five Facet Mindfulness Questionnaire (FFMQ)

This self-report assessment was created using factor analysis of the combined questions from five recent mindfulness meditation questionnaires shown to have internal consistencies ranging from .71-.91. The resulting assessment contains 39 questions based on factors with minimal loadings of 0.40 and a difference between loadings of at least 0.20 between the highest and next highest factor, yielding five main facets of mindfulness. The facets include nonreactivity to inner experiences,

observing/noticing/attending to sensations thoughts and feelings, acting with awareness, describing experience, and nonjudging of experience (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006).

Balanced Emotional Empathy Scale (BEES)

The BEES scale is designed to measure the trait of empathy defined as the ability to “vicariously experience the emotional experience of others” (Mehrabian, 2000). The scale consists of 30 questions with a 9-point scale reflecting amount of agreement. The scale has been used in over a dozen studies including one neuroimaging study examining brain correlates of empathy (Singer et al., 2004). The coefficient alpha internal consistency of the BEES is .87 (Mehrabian, 1997). The initial validity of the instrument is supported by a positive correlation of .77 with the Emotional Tendency Scale (Mehrabian & Epstein, 1972).

Mysticism Scale (M Scale)

The M Scale is a self-report instrument designed to measure an individual’s peak experience of unity using eight of the nine criteria described by Stace (1960) as indicative of a mystical experience (Hood, 1975). The scale has been shown to produce a three-factor solution with respective alpha coefficients; “introvertive” or unity with “nothingness” (.69), “extrovertive” (.76) or unity with the outside world, and religious interpretation (.76) (Hood, Morris, & Watson, 1993). The scale has been used in a prior meditation study (Wachholtz & Pargament, 2005).

Meditation Depth Questionnaire (MDQ)

The purpose of this questionnaire was to identify a universal dimension of “meditation depth” regardless of spiritual tradition (Piron, 2001). The questionnaire was constructed based on the interview of 45 authorized meditation teachers providing information concerning the depth of different experiences yielding 5 clusters within 30 questions. The scale was tested in 122 advanced meditators of various traditions supporting the uni-dimensionality of the scale with 29 items load from 0.72 to 0.93 on one and the same factor. There was a significant difference between meditation practitioners who practiced at least 11 years and those who practiced less than 11 years on MDQ scores. Both discriminant and convergent validity were shown to be supported in comparisons with other instruments, and the split-half-reliability according to Spearman-Brown was 0.90 (Piron, 2001).

Exploratory Compassion Scale (ECS)

The ECS is an experimental set of 39 items embedded in a more generic set of spiritual questions created using the phenomenological literature referenced above. The purpose of these questions was to begin building a data set for the future development of a standardized scale that would require a much higher number of subjects for formal scale development. However, since there were no formal previously validated compassion scales with adequate psychometric properties in the known scientific literature, the mean from these questions was used to provide some metric for estimating compassion trait presence (see Appendix B).

Procedures

Potential participants were screened by phone or E-mail to determine if inclusion criteria were met and to explain the requirements of the study. Those participants choosing to participate were sent by E-mail electronic scales and general information forms before participation in the neuroimaging. These forms remained de-identified prior to consent into the study in order to allow data gathering and confirmation that the criteria for inclusion were met. The subjects were not compensated for their participation.

When subjects arrived for testing formal Institutional Review Board approved consent was obtained for all procedures listed. For purposes of the current study four validated measures were used to examine the consistency of putative improved general spiritual traits. A fifth scale, the BEES, related to empathy was administered in an attempt to capture, with a validated instrument, at least one facet of compassion.

Neuroimaging Protocol

The study employed the following brain recording measurements using three types of neuroimaging modalities. For MRI this included: functional MRI (fMRI) of meditation state, structural brain volume calculations, and diffusion tensor imaging (DTI). Magnetoencephalography (MEG) and electroencephalography (EEG) were collected simultaneously during the following study components: baseline recordings at rest, meditation state for practitioners, or alert relaxation in controls , induced compassion state, subconscious affective picture processing event related potential (ERP), emotional Stroop ERP, theory of mind ERP, and necker cube shifting ERP paradigm. While these tasks were done as part of the broader exploratory investigation of advance meditators,

only the details of the induced compassion task are presented. The total time for neuroimaging was between 4-6 hours depending on number of breaks and timing of the tasks during the day.

MEG Data Collection

The MEG data were collected with a 306 channel Neuromag Vectorview at a sampling rate of 973 Hz, with a low frequency filter of 0.03, and a high frequency filter of 320 hz. Where time permitted, an additional 60 channels of EEG was collected using an ANT electrode cap. The impedances were set at or below 120 kilo-ohms. A nasal cannula was placed under the nostrils to record respiratory rate. An electro-oculogram was collected by placing an electrode on the upper right eye 1 cm from outer canthus, and the second electrode 1 cm from the outer left eye canthus. A set of cardiac leads was placed on the left and right upper clavicles. These later two bipolar electrode sets were used to assist in the removal of artifact.

The data files were subjected to signal space separation processing to remove externally generated magnetic artifact using the vendor supplied Maxfilter software application (Taulu & Simola, 2006). The BESA software package version 5.3 (BESA GmBh, 2011) was used to mark and analyze frequency spectrum in the MEG epochs. The calculated spectral values were then imported to Excel spread sheets for averaging.

Induced Compassion Task

The neuroimaging task was designed to induce an authentic subjective state of compassion within research participants while recording brain activity. A further goal was to validate that such a subjective experience occurred during the recording period.

This task consisted of describing a real scenario to participants based on an actual eyewitness account of what a child experienced during and after an event. The account is based on an actual interview with the photojournalist who took the picture at the scene. The scenario was presented in a written form on a nonmagnetic screen that was projected into the MEG room.

Prior to starting the task participants were instructed verbally they would be presented with a real scenario, and to “think of the child as a real person, right now, out in the real world.” The scenario described how the child’s parents failed to stop at a check point in a war zone and then were violently killed by massive machine gun fire in front of the child. The picture of the child was taken seconds after the event took place, and depicts a small crying child splattered with her parent’s blood . When the picture was presented participants were instructed to keep their eyes focused on the child and to generate a feeling of compassion for her. Immediately after viewing the child but while the scanning continued participants answered questions concerning their feelings about the child. The participants were then given a repeat scenario in which they were told the story was actually completely made up and that the child was actually just an actress performing a play. They were then shown the picture again and asked to report their feelings immediately after.

This state of compassion during the MEG task was measured in two ways: 1) By simply asking the subject to rate their level of compassion for the child in the picture while reflecting on their experience during the “real” compassion condition using a 0-4 scale at the end of the entire task. This was referred to as the “overall compassion rating”

and was done only one time as a single overall rating. 2) By using the results from the SAM rating scale and summing the 0-8 rating for each of the terms “love” and “sadness” to create a compassion composite score.

The value rated for the “fake” condition was then subtracted from the rating acquired for the “real” condition. The subtracted value was referred to as the “compassion composite difference score”. In an analogous manner using the exact same rating and summation procedure outlined above the terms “anger” and “spite” were used to create a “composite anger difference score”. This later measure was implemented to test for the risk that the task could inadvertently also induce a contradictory emotion that contaminated the primary target emotional state.

These ratings were collected “online” during the recording of brain electromagnetic data as a way to improve neuroimaging methodology in linking measurements to subjective states (Northoff & Heinzel, 2006).

Data Analysis

The data in the MEG file were subjected to signal source space separation methods to eliminate magnetic signals extraneous to the head space. The “cleaned” file was then reviewed for additional artifacts and 1-second artifact free segments were identified for analysis. The segments were fast Fourier transformed and then the average frequency was calculated from the combination of 24 segments for the gamma (25-42 Hz) and alpha band activity (4-13 Hz). The gamma band was then divided by the alpha power value to create a relative gamma-alpha band ratio value for three groupings of gradiometers: a left fronto-temporal grouping (36 gradiometers), a right fronto-temporal grouping (36

gradiometers), and a mostly midline frontal array (40 gradiometers). The values were log transformed and averaged for each gradiometer grouping.

The use of a relative gamma to alpha ratio is important to help in enhancing results where muscle contamination is a known confound (Shackman et al., 2009). The use of a grouping was selected because of the small sample size and precedent in the experimental literature for demonstrating dominant fMRI and EEG findings within fronto-temporal regions of the brain during tasks directly or indirectly related to compassion and empathy. A repeated measures MANOVA with one between group factor (control and long-term meditator) and the differences between the three gamma/alpha band gradiometer cluster averages constituted the dependent variables for the control fake condition and the real compassion exposure condition. The use of three gamma/alpha bands and a hypothesized large effect size similar to the finding of Lutz et al. (2004), indicated a sample size of 10 within each group was more than sufficient to achieve a power value of .80, at an alpha of .05.

For each gradiometer gamma/alpha band sensor cluster an average difference was computed between the fake and real compassion conditions. A correlational analysis was done with the MEDEQ, years of meditation practice, FFMQ, ECS and M-scale for each group. To determine whether groups showed significant differences among instruments designed to assess meditation development, a series of two-tailed t-tests was conducted for the FFMQ, MEDEQ, FACIT-Sp, M-scale, and the ECS.

CHAPTER III

RESULTS

Group Comparability

Twenty healthy participants were recruited with 10 participants assigned to each group. The demographic characteristics of the participants were highly similar (Table 1). The average age of the advanced meditators was slightly higher, being two years higher than the controls. The groups were identical with respect to gender, and academic achievement. All participants were college educated with 80% of the subjects having a graduate level degree in both groups. The ethnicity was nearly identical with two meditators being Asian Americans. According to the recruitment requirements of the study there was a clear difference in reported hours of meditation practice. The majority of the controls lacked prior meditation practice, or reported some (<30 hours) total lifetime meditation practice indicated as an informal practice, i.e., not under the long-term direction of a spiritual teacher, or as part of a formal meditation based religious system. Therefore the recruitment goal of having closely matched characteristics with the exception of having a dedicated meditation practice was met.

Although controls were carefully screened to insure no, or minimal meditation practice exposure, the possibility existed that control participants could be “enlightened” or spiritually advanced through other means. The reverse possibility was that the Zen practitioners, in spite of being selected by an advanced teacher as having developed

significant spiritual realization and/or having met rigorous religious “rank” standards, were not authentically spiritually advanced. To help address this possibility, hypothesis one predicted that measures with good psychometric properties based on their previous use in both meditation and nonmeditation subjects would show significant differences between the groups. The results in Table 2 demonstrate that all of the measures were higher in the Zen Practitioners as predicted by their hypothesized enhanced level of spiritual development. However, only the MDQ, FFMQ, ECS, and FACIT showed statistically significant differences. That the majority of scales showed statistically significant differences strengthens the assertion that practitioners chosen by their tradition as being spiritually accomplished had reached a higher level of spiritual understanding.

Compassion Task Effectiveness

Zen practitioners during the induction of compassion in the MEG scanner were expected to report higher levels of compassion towards the person who experienced a tragedy as compared to controls. This was important not only to determine if Zen practitioners have by virtue of their spiritual training an enhanced subjective compassion response, but also to determine if the task itself was effective in inducing compassion across all subjects.

A paired-sample t-test was conducted to evaluate the overall compassion rating between groups. There was a statistically significant increase in the Zen practitioners ($M=3.75$, $SD=.46$), as compared to controls ($M=3.20$, $SD=.63$), $t(18)=-2.49$, $p<.001$. The eta squared statistic (.21) indicated a large effect size (see Figure 1). A repeated measures analysis of variance was conducted to assess the impact of the two different conditions

(real vs. fake) on the subject's composite compassion scores according to group (control vs. Zen practitioner) . There was a statistically significant main effect for the compassion condition $F(1, 18)=36.31, p=.000$, with a large effect size, eta squared of .67 (see Figure 2). However the group by condition interaction was not statistically significant, $F(1,18)=1.09, p=.31$ even though the Zen practitioners did demonstrate a higher average score ($M=14.0, SD=2.1$) compared to the controls ($M=12.0, SD=2.5$). The anger composite difference scores were noted to be similar and low in the Zen practitioners ($M=3.1, SD=3.1$) and controls ($M=2.1, SD=2.3$) especially when considering the potential ceiling of 16. A repeated measures analysis of variance was conducted to assess the impact of the two different conditions (real vs. fake) on the subject's composite anger scores according to group (control vs. Zen practitioner) . There was a statistically significant main effect for the real vs. fake conditions $F(1, 18)=12.8 p=.002$, with a large effect size, eta squared of .47. However the group by condition interaction in anger was not statistically significant, $F(1,18)=.474, p=.50$ indicating the differences between real and fake conditions were similar in control and meditator groups.

The overall result indicates that the task was effective in bringing about a subjective experience that was qualitatively different in the two conditions, with advanced practitioners having a somewhat higher level of self-reported compassionate response. While some contaminate emotion of anger was noted as being significant, this was in the low range compared to the metric of the compassion difference score, with groups being nearly equal in their response change magnitude.

The subjective ratings of reported emotion collectively indicate that the task was effective in inducing compassion to a significant degree, and that the presence of anger was minor, likely posing no threat to the effectiveness of the task for comparison purposes.

Neuromagnetic Recordings of Task Effects

The averaged gradiometer spectral data were converted to topographic sensor maps for each subject before analysis and visually inspected for overall distribution patterns. In all cases, regional gamma band activation was distributed frontally and temporally. There was no indication that the occipital or parietal sensor regions not included in the statistical analysis, held the dominant activation patterns. Therefore, the first component of hypothesis one, that the gamma/alpha activity would be distributed with concentration frontally and temporally, was supported.

The regional cluster averages of gradiometer recorded gamma/alpha band ratio activity were subjected to a repeated measures MANOVA. There was a single between group factor (control versus long-term meditator), and the dependent variables were in the fake and real compassion condition gamma/alpha band ratio gradiometer averages for left frontal-temporal, central frontal, and right frontal-temporal regions.

The main effect for the task was not significant $F(3, 16)=1.105$, $p=.376$; Wilks' Lambda=.828, nor was the task by group interaction $F(3,16)=.855$, $p=0.484$; Wilks' Lambda=.862. While there was no significant main effect noted by group, when difference scores between the real and fake condition are plotted by region (Figure 3) it can be seen that there is a substantial difference between conditions in the Zen group, and

a small amount of change in the control group. The magnitude of change from left frontal, central, right frontal were 3.6, 10.9, and 23.8 times, respectively. These values had a large degree of variability, and the difference in activity between real and fake were calculated with the advanced meditator group having an overall lower set of starting control condition values.

When the above data sets were examined in more detail it was found the majority of subjects in both groups showed a large amount of variation between real and fake ratios (Table 3). The characteristics of the meditation practitioners having high change scores ($>.03$ or $1\ SD$) showed the extreme responders were all high ranking according to their religious tradition. This group consisted of a total of three Roshis and one Sensei. In addition, with the exception of the high scoring Sensei with 5500 hours of lifetime meditation practice, the extreme responders all possessed the highest levels of lifetime meditation hours. Their lifetime meditation hours were: 45,000 and 70,000 hours respectively. When the control group was examined using the same criteria there were two responders with change scores of similar magnitude. The central frontal area showed a similar pattern with three of the same Roshis and two of the same control subjects having differences between real and fake greater than $>.03$.

For the right fronto-temporal region the situation was more dramatic, with two advanced Zen practitioners having a change difference score above $.03$, as compared to none of the controls exceeding this threshold. These two extreme responders were the same practitioners with the highest amount of lifetime meditation practice noted above in the left and central regions. Thus, while a significant increase in alpha/gamma band

activation did not occur during the real condition as predicted, there was a trend for advanced Zen practitioners to generate more gamma/alpha band activity and for this activity to show relationship to amount of training and rank. The overall trend of more extreme activation changes can best be described as an activation pattern moving from a more commonly occurring left front-temporal activation in both groups to a concurrent right fronto-temporal activation pattern unique to the most experienced Roshis. These observations were further supported below by statistically significant increasing correlations from left to right brain activations patterns and hours of lifetime meditation practice (Table 4).

Correlations of Compassion State Measures and

Neuromagnetic Activity

A Pearson product-moment correlation coefficient was computed for each of the three brain region gamma/alpha averages and the subjective compassion state and trait score values. The compassion state results are summarized in Table 4, and trait measures in Table 5. In neither case were there significant correlations with gamma/alpha activity.

Therefore, the prediction that the state measure compassion composite difference score and compassion trait measures would correlate with the gamma/alpha difference between conditions was not supported.

Correlations of Spiritual Trait Measures

and Neuromagnetic Activity

The situation is somewhat different for the remaining spiritual trait scale items where one of the four scales, the FFMQ demonstrated previously to be significantly different

between the groups, along with the total hours of lifetime meditation showed a statistically significant relationship with gamma/alpha band activity (Table 5). The prediction that trait measures of spiritual enhancement would correlate with gamma/alpha difference scores was, therefore, partially supported.

It is of interest that while the remaining two scale scores the FACIT and MDQ were demonstrated previously to be significantly different between groups, they did not show a statistically significant relationship with the gamma/alpha bands. This is in spite of them showing a significant correlation with the FFMQ and each other. Unlike the remaining measures, in the case of the M-scale and BEES a lack of relationship to the FFMQ is not surprising considering meditators and controls did not differ significantly on the measures to begin with.

Table 1

Characteristics of Subjects

Group	Controls (<i>n</i> =10)	Advanced Zen Practitioners (<i>n</i> =10)
Gender		
Male	5	5
Female	5	5
Average Age	56.9 (<i>SD</i> 5.8)	59.9 (<i>SD</i> 13.7)
Education Level		
Graduate degree	8	8
Undergraduate degree	1	1
Some College	1	1
Ethnicity		
White	10	8
Asian American	0	2
Religion		
Christian	5	0
Buddhist	1	10
Nonspecific	4	0
Zen Soto Religious Rank		
Roshi	0	4
Sensei	0	2
Hoshi	0	4
Lifetime Hours of Meditation		
Group average	4	22750
Range	(0-20)	(2500-70000)

Table 2

Spiritual Scale Score Means By Order of Significance and Effect Size

	Controls	Zen Practitioners	η^2
Scale	(<i>df</i> =10)	(<i>df</i> =8 & 10) ^a	
	Mean (<i>SD</i>)	Mean (<i>SD</i>)	
Meditation Depth Questionnaire	46.5 (24.6)	87.4 ^{**} (14.7)	0.50
Five Facets of Mindfulness Questionnaire	135.4 (19.0)	159.9 [*] (12.8)	0.38
The Functional Assessment of Chronic Illness-Spiritual-Extended	66.9 (22.2)	86.9 [*] (6.4)	0.27
Experimental Compassion Survey	82.3 (23.7)	101.4 [*] (10.8)	0.20
Balanced Emotional Empathy Scale	50.6 (23.3)	67.5 (22.7)	0.13
Mysticism Scale	113.8 (30.0)	122.1 (34.5)	0.02

^a The FFMQ, M-Scale, FACIT, and BEES have 8 subjects in the Zen practitioner's group.

Significant difference at ^{*} $p \leq .05$, ^{**} $p \leq .001$

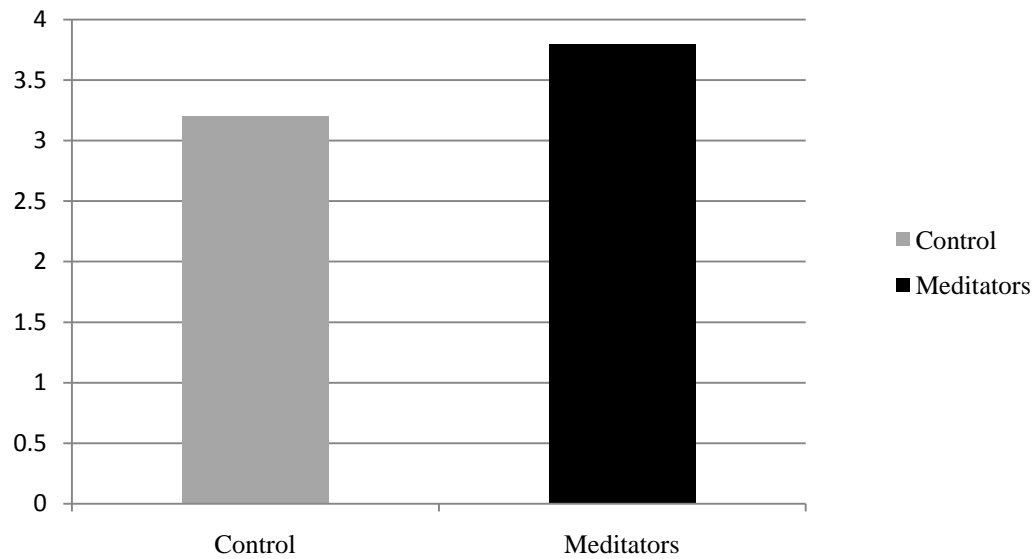


Figure 1. Bar graph showing the average level of overall self-rated compassion (possible range 0-4) by group while viewing the girl during the real condition

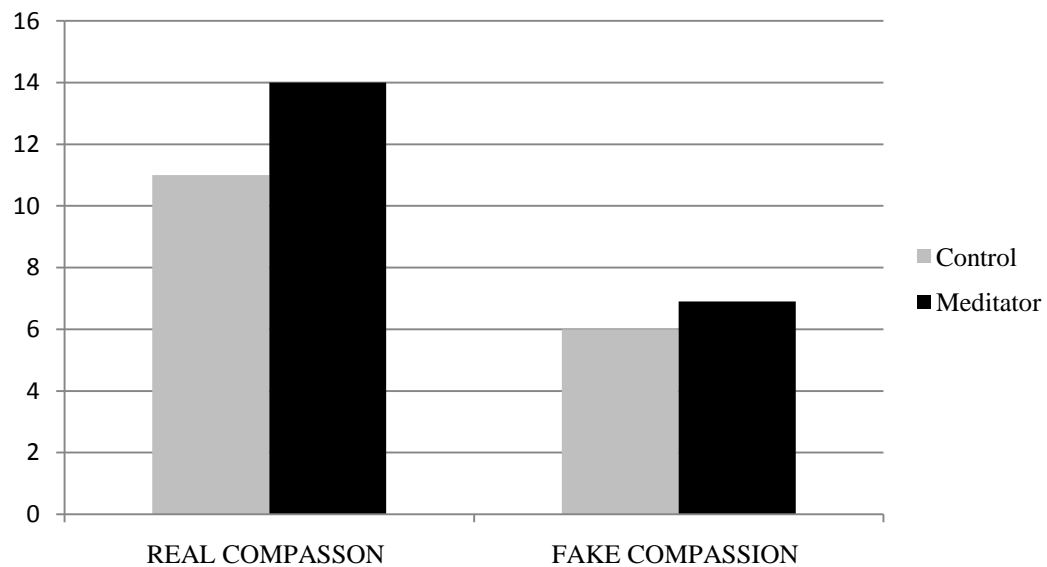


Figure 2. Bar graph showing the average level of self-rated compassion using the composite compassion SAM scale (range 0-16) according to condition (real vs. fake) by group.

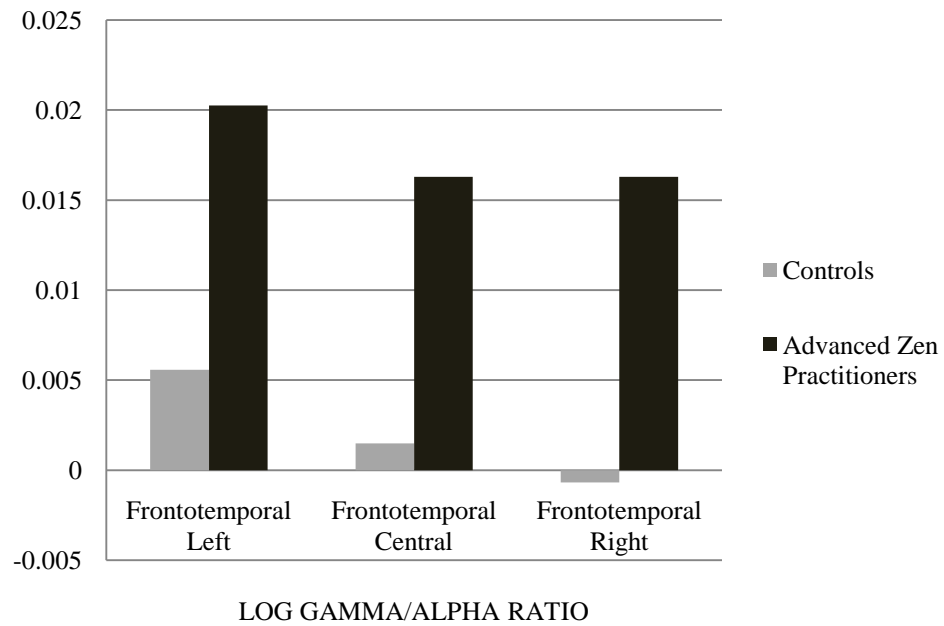


Figure 3. Bar graph showing the total difference score averages between the real and fake compassion conditions according to brain regions and group.

Table 3

Neuromagnetic Regional Alpha/Gamma Averages Per Task

Variable	Controls		Zen Practitioners	
	Mean	SD	Mean	SD
Fake Compassion				
Left Frontotemporal	0.907	0.083	0.863	0.040
Central	0.922	0.074	0.888	0.055
Right Frontotemporal	0.899	0.073	0.870	0.057
Real Compassion				
Left Frontotemporal	0.913	0.079	0.883	0.048
Central	0.923	0.076	0.905	0.060
Right Frontotemporal	0.898	0.073	0.886	0.068
Difference Scores				
Left Frontotemporal	0.006	0.034	0.020	0.028
Central	0.001	0.028	0.016	0.021
Right Frontotemporal	-0.001	0.021	0.016	0.024

Table 4

Compassion State Measures and MEG Gamma/Alpha Correlations

Variables*	1	2	3	4	5	6	7
1. Left Frontal Gamma/Alpha Change	—						
2. Central Frontal Gamma/Alpha Change	.742**	—					
3. Right Frontal Gamma/Alpha Change	.657**	.722**	—				
4. Real-Fake Composite Difference Score	-0.336	0.005	-0.106	—			
5. Overall Compassion Rating	-0.038	0.125	0.228	.162	—		
6. Composite Compassion-Real Condition	.207	.097	.305	.121	.506*	—	
7. Composite Compassion-Fake Condition	-.153	-.099	-.038	-.095	.183	.301	—
<i>M</i>	0.0129	0.008	0.007	6.30	3.50	12.50	6.45
<i>SD</i>	0.031	0.025	0.023	4.28	0.61	2.74	4.59
Possible Range	0-1	0-1	0-1	0-16	0-4	0-16	0-16

* $p \leq .05$, ** $p \leq .001$

Table 5

Spiritual Trait Measures and MEG Gamma/Alpha Correlations

Variables	1	2	3	4	5	6	7	8	9	10
1. Left Frontal Gamma/Alpha Change	—									
2. Central Frontal Gamma/Alpha Change	.741**	—								
3. Right Frontal Gamma/Alpha Change	.656**	.722**	—							
4. Total Lifetime Meditation Hours	.461*	.509*	.679**	—						
5. Five Facets of Mindfulness Questionnaire	.474*	.613**	.410*	.468*	—					
6. Meditation Depth Questionnaire	0.214	0.316	0.269	0.442	.802***	—				
7. The Functional Assessment of Chronic Illness-Extended	0.239	0.354	0.279	0.381	.719***	.712***	—			
8. Balanced Emotional Empathy Scale	-0.258	0.079	-0.049	0.175	0.202	0.31	.416*	—		
9. Mysticism Scale	-0.053	0.121	0.193	0.277	.504*	0.39	.492*	0.195	—	
10. Experimental Compassion Scale	-0.111	-0.027	0.147	0.329	0.434	.509*	.706**	.492*	0.277	—
<i>M</i>	0.013	0.008	0.007	10252	146.2	66.9	75.7	58.1	117.5	90.7
<i>SD</i>	0.031	0.025	0.023	18333	20.4	28.7	19.6	23.9	31.3	21.7
Possible Range	-1-1	-1-1	0-1	0-70000	0-120	39-195	0-120	0-120	32-160	0-156

* $p < .05$. ** $p < .01$. *** $p < .001$.

CHAPTER 4

DISCUSSION

The purpose of the present study was to test a highly trained group of Zen practitioners for the presence of compassion ability both subjectively and neurophysiologically using a novel magnetoencephalographic-based task. The study also sought to demonstrate spiritual traits through the use of previously standardized measures and to begin the process of developing measures relevant to the investigation of compassion. The measurement of compassion included not only a novel trait measure, the ECS, but also a compassion-based subjective state measure that can be integrated within a neuroimaging task for the development of a “first person neuroscience” compassion-based methodology (Northoff & Heinzel, 2006).

Trait Measures

Four of the six scales that measure mindfulness, general spirituality, mysticism, empathy, and deep meditation state distinguished meditators and controls. These findings demonstrate the value of using an “expert” Roshi to select those who are spiritually developed. The MDQ, FFMQ and FACIT were highly inter-correlated. The correlation between the MDQ and FFMQ was not surprising considering both were developed in a Buddhist context. In contrast, the FACIT was created in a secular context and the authors claim to make no assumptions about religious background (Peterman et al., 2002). The

correlation of the MDQ and FFMQ with the FACIT, and the finding that the FACIT was significantly different between the groups provides some support for the conclusion that the control subjects were not lower on these measures merely because of a lack of exposure to Buddhist training.

The BEES, ECS, lifetime hours of meditation, and M-Scale correlated with some of the above measures but not all. The most surprising finding was that life time hours of meditation practice correlated strongly with only one scale, the FFMQ. The FFMQ was also correlated with the M-scale. That the FFMQ correlated well with the majority of other measures and high spiritual development as suggested by a high level Roshi suggests that previous research validating its use in advanced mindfulness meditation practitioners (Baer et al., 2008) has utility in Zen practice as well. The FFMQ currently represents the most extensively developed instrument for gauging meditation practices involving enhanced awareness of the totality of conscious experience, openness, or “mindfulness” (Baer et al., 2006; Kabat-Zinn, 2005). The scale’s sensitivity to Zen-based practices is not surprising given that the term “mindfulness” meditation practice refers to one of the types of meditation used in Zen practice that is the less concentrative and a more open form of meditation commonly described in the Zen literature (D. Suzuki, 1964).

The lack of a significant difference between groups using the M-scale is surprising given that the scale purports to capture not only the highest spiritual trait resulting specifically from the meditation practice described above, but also that of the highest understanding coming from the concentrative form of meditation practice as well (Hood

et al., 1993). The use of both forms of meditation to eventually achieve a sense of total unity (nonduality) that then is grounded back into the real world with great awareness (compassion) is considered the pinnacle of the Zen mystical tradition (Yamada & Hori, 2004). The practice of Zen is considered to be a strong religious system for achieving a mystical or nondual state (Merton, 1967; Wilber, 2000). The usefulness of the M-scale may be more limited to samples from populations of the non-Buddhist mystical traditions that it was developed upon.

The lack of statistical significance found with the empathy measure (BEES) was disappointing. It was expected that this validated instrument could be used to capture at least one facet of compassion development. The instrument is described as capturing “individual differences in the tendency to feel and vicariously experience the emotional experiences of others” (Mehrabian, 2000, pg1). While the scale has been used in previous work (Shapiro, 2004) including one neuroimaging study (Singer et al., 2004), the lack of differentiation may be related to the more generic aspect of empathy the scale was designed to measure. The fact the scale that was developed on 91 undergraduate students (Mehrabian & Epstein, 1972) supports this contention. The small sample size and younger college age group raises questions related to external validity, particularly when the scale is used on an older age group. In addition, the construct of higher level Buddhist compassion involves the more abstract notions of “selfless” practice, or the notion the other is identical to self, which is also the totality of reality. The paradox is then there is no differentiation at the same time extraordinary value is placed upon the individual (Dalai Lama et al., 2001).

The ECS questions were derived from writings that reflect this higher level of spiritual compassion, and unlike the BEES, it showed a statistically significant difference between groups. While this initial set of findings is enticing, scale development requires a broad sampling from the population to ensure validity. The minimum number of subjects is generally considered at least 300 (Nunnally, 1972). The small sample size in the current study precludes further scale development but indicates the importance of using the ECS with a larger number of participants in future studies.

The support for the first component of hypothesis one, that scales can distinguish the meditation group from controls, also adds validation to the process used to select meditator participants. The Zen practitioners recruited for this study were selected based on the recommendation of an advanced Zen Roshi, or official Zen Master who knew the individuals personally through years of personal training, or knew they had met criteria (the other Roshis) through rigorous criteria set by the religious tradition itself. The use of an advanced Zen Roshi to both identify those who “officially” have earned this title, as well as to recruit those with lower ranking but considered to have adequate insight was critical to ascertaining a spiritually experienced sample. The practice of using an expert sanctioned by the religious tradition is typically not described as being used to recruit experienced meditation subjects in meditation studies. What is typically described are participants being considered advanced by virtue of their years of training or number of hours of meditation. This later approach is problematic as a person can stay in a highly dedicated practice and yet still not advance. The Roshis who participated in the present study indicated they knew of numerous people who even after 20 years or more of

dedicated practice, including in some cases monastic life, had not developed spiritually to any significant degree. They indicated that intuition and dialogue involving tests set by the religion would determine for them ultimately where a student was in their spiritual understanding. Therefore, the present study made a novel attempt to bring expert religious evaluation to bear on acquiring a sample of advanced enlightened meditators and assess the construct validity of the chosen scales. The importance of this approach cannot be overstated. The issue of what is measured given the complexities of descriptive word usage, and the various subtleties of mental states has posed a major problem in other fields where characterization of human behavior is vital (Bearden, Reus, & Freimer, 2004). The exclusive reliance upon scales alone can therefore be problematic especially when investigating religious and spiritual phenomena where cultural and personal factors play a large role in dictating a person's response (Hill & Pargament, 2008; Sandoval, Hancock, Poythress, Edens, & Lilienfeld, 2000).

The second rationale for using scales to evaluate spiritual development in groups is that spiritual understanding or insight can occur in the absence of any formal religious or spiritual practice. This is similar to mathematical savants who can perform complex mathematical calculations without any formal college training that typically would require years of advanced college course work (Baroody & Dowker, 2003). The idea that you can have no meditation, or other religious practice, and still have extraordinary spiritual understanding is well known in historical Zen tradition (Gregory & Kuroda Institute., 1987). What is called enlightenment in Zen is not specific to Zen, and is considered consistent with the higher levels of spiritual development present in other

spiritual traditions (Merton, 1967). In this regard, the danger existed that the control group possessed an understanding from nonmeditative traditions and practices. The use of scales having presumed ability to tap spiritual understanding therefore helped control for this possibility.

Compassion Scales

The effectiveness of the compassion neuroimaging task, and the second part of the first hypothesis that the neuroimaging compassion state measure and compassion trait measures would be significantly different between controls and meditators was mostly confirmed. The exception was the composite compassion score that did not distinguish significantly between groups but was elevated in the Zen practitioners. This is important as the scenario was selected to generate a strong emotional response in people regardless of spiritual training. A danger of the task was that both groups would have too strong of an emotional response thus pushing both brain and subjective ratings to a theoretical ceiling. The use of a real scenario, paired with an actual picture taken from the scenario appeared to be effective. The compassion composite during the real task was highly correlated to the ECS, followed by a weaker, but significant correlation with the BEES. These correlations support the construct validity of the single neuroimaging task scales. Since the simple self rating correlated with the BEES, the composite self-rating may have more predictive validity (DeVellis, 2003).

Compassion Induced Neuromagnetic Activity

The lack of a strong finding for the compassion induced neuromagnetic activity, along with lack of significant correlation with subjective state measures postulated by hypothesis two, may have occurred for a number of reasons:

1) The gamma response may be weaker than expected and therefore more susceptible to random noise (subject moving slightly, thinking about other things, etc.). The task because of duration (20-30 minutes on average) in the context of subjects needing to complete other tasks, sought one exposure to the experimental condition. This was done because once the subject was aware deception was being used as part of the experimental paradigm they would be less likely to respond naturally in subsequent trials. This single design type was thought to be adequate given the report by Lutz et al. (2004), which showed very large gamma band responses in Tibetan meditators. However, the present study differed in that Zen rather than Tibetan practitioners were used, and the subjects were being asked to generate a natural state of compassion as opposed to a formal meditation based compassion unique to Tibetan meditation practice. While a great deal of effort was made to select stable, noise free segments for analysis, a single trial design may be inadequate to discern prolonged evoked activity.

2) The baseline state of an advanced Zen practitioner may be different than the controls. The most consistent finding in the meditation literature on overall brain wave changes in advanced meditation practitioners suggests enhanced alpha band distributions in the EEG (Fell et al., 2010). The testing of awake baselines to specifically examine for sustained enhanced alpha has not been done in meditators during a normal wakefulness

state. However, if this is the case in the group of advanced practitioners used in the present study then the use of the gamma/alpha ratio would have a propensity to be lower for all the brain regions in question compared to the controls in the fake compassion condition. If indeed gamma activation is a marker for compassion experience, this would allow for more robust changes to be noted in the advanced Zen practitioners as neuronal networks shift from alpha to gamma frequency activations.

3) The compassion response may be mediated by nongamma brain activation patterns. What was picked up in the current study may actually be noise secondary to both random and perhaps task-linked muscular activations as noted in other gamma band task studies (Pope, Fitzgibbon, Lewis, Whitham, & Willoughby, 2009). This was partially controlled for by careful visual analysis of EEG, MEG, and facial EMG segments. The use of a gamma/alpha ratio was used as the primary control method to further counteract this problem. However, muscle artifact, particularly in the gamma band can be subtle. Since the scientific literature is limited to one spectral compassion-based paper (Lutz et al., 2004), the question remains if the core findings in the study by Lutz as well as the current study may be more attributable to muscle artifact than actual brain activations? There also remains the question of whether gamma band response is really the best marker as there was no indication that other spectral bands were investigated in the paper by Lutz. A study using a task overlapping with the construct of compassion demonstrated delta, not gamma, during emotional processing (Basar et al., 2008).

In spite of these possible alternative explanations, the finding that four of six of the highest ranking Zen practitioners (and none of the Hoshis) showed high ($>1 SD$) left

sided gamma/alpha activations compared with only two of the controls is intriguing. The additional finding of the two most experienced Zen practitioners exclusively showing parallel high right-sided activations adds to suggestion the practitioners have a unique activation profile. These findings suggest that high bilateral gamma/alpha activity may be a marker for enhanced compassion ability related to meditation experience.

Limitations

The present study's most limiting factor was the small sample size. This was particularly problematic in the case of recording gamma band related activity where, in spite of using highly sensitive MEG gradiometers, and strict artifact rejection criteria, gamma band activity did not reach expected levels. The relationship of the self-report scales to each other, as well as the gamma band activity while intriguing also suffers from this difficulty. Statistical power was low, leading to the possibility of an increased false negative rate particularly in the case of the gamma band activity. The effect may have been attenuated because of task design, where once a person had an emotional response, they may have carried over part of the emotional, or compassion response to the "fake" scenario, even though they report having no or minimal affective compassionate feelings. Therefore, the task may have inadvertently not tested compassion directly but the ability of a subject to change emotional mind sets, i.e., to switch gears emotionally. This ability has been reported previously in meditation practitioners (Aftanas & Golosheykin, 2005), and is known to vary among nonmeditation subjects (Kross, Davidson, 2009). This would imply that advanced meditation practitioners in the current study were better at emotional regulation ability. Rather than generating a unique compassion brain state, the meditators

generated a large amount of gamma along with the controls but only the advanced practitioners could truly experience the child on an emotional level differently a few minutes later.

While the multitude of problems associated with a small sample size are well known, it is important to view this limitation in the context of what is gained by doing exploratory work with a very rare sample of practitioners, most of whom can be considered meditation “Olympic level athletes”. Gladwell discussed the importance of studying individuals with exceptional skills, where 10,000 hours or more of dedicated practice is considered the necessary minimum amount of time required in nearly any given profession to achieve expert status (2008). In the neurosciences, the study of extreme outliers, even where the $n=1$, has led to numerous investigations producing very valuable knowledge into brain functions that would have not been possible otherwise (Spector & Maurer, 2009).

The second limitation is that the advanced Zen practitioners were selected through predominantly expert judgment, and personal connection to a single religious leader as described earlier. This further reduces the generalizability of the findings to other Zen practitioners. There are well known differences in philosophies, meditation training, and practices among differing Zen lineages and centers that may limit traits or even brain activation patterns.

The third limitation is that strength of the correlation between measures depends not only upon the traits they reflect, but also on the reliability of those measures. Even very well developed measures have test-retest reliabilities centering between .70 and .80, and

they rarely exceed .90 (Crocker & Algina, 1986). The situation for task-related gamma band activation induced is unknown as no scientific work on this could be found.

However, for fMRI studies repeat tasks can average between .4 and .7 (Johnstone et al., 2005; Manoach et al., 2001). A review of over 20 papers in nontask related EEG power spectral values concluded there was an exponential increase in reliability moving from .80 reliability for epochs of 20 seconds to .90 for a 40-second segment (Thatcher, 2010). Although it may well have been the task-related segments used in the current study did have adequate reliability, the question remains of how much reliance can be placed on the results found.

Future Directions

A major improvement in the design of this study would be to include a repeat version of the compassion task done in blocks. In this case four pictures and scenarios presented under the “real” block, and then four under the “fake” condition would be realistically possible given the practicalities of keeping subjects in the scanner for longer periods of time. The presentation of the blocks could then be split with half of subjects receiving the fake set of blocks first, and the other half receiving the real scenarios second. This would then control for an emotion carry-over effect, and further to allow a within-task repeat testing to help in averaging out random variation. The other important component to add is a simple resting state, eyes open, baseline recording to see if the baseline state in an advanced Zen practitioner is on average different from a control. A segment of equivalent duration used in the compassion induction task could then be collected and used as a covariate in a MANCOVA analysis. If the sample size was larger, additional dependent

variables could be added to include the lower frequency bands, i.e. delta, theta, and alpha by itself.

Although it was argued previously that the use of an advanced Roshi to select subjects using expert judgment helped to enhance subject selection and added validity, there was also noted the danger of bias. A future study could include the use of several Roshis or equivalent religious leader from other meditation traditions who would be given the task of blindly interviewing subjects to determine their level of spiritual understanding. The control subjects and meditators would be subjected to the same interview process, and the determination of a person's level of spiritual development could then be decided by expert consensus. Where there was marked disagreement in a person's spiritual level, repeat interviews could be done for clarification followed by discussion among the experts of the person's status. This process is similar to what is done in psychiatric genetics work to insure accurate identification of the phenotype. In a similar manner, it raises the question of whether semistructured interviews that are commonly used in psychiatric genetics work could be developed in the spiritual domain to capture universal elements of spiritual development. Such measures could incorporate some level of flexibility regarding religious terminology in order to avoid bias caused by potential misunderstanding of terms by the subject. The parallel use of qualitative research methods could greatly benefit the development of scales in this largely uncharted domain of human functioning.

Finally, because the simple self compassion rating scale did not correlate as highly with other measures compared to the composite compassion rating scale, the construction

of a more elaborate emotional compassion-based scale may improve content validity. The term compassion can mean different things to different people, and there are different levels of compassion noted within the spiritual traditions themselves (Wilber, 1995). Therefore, the subject must be given emotional dimensions that tap dimensions of compassion most consistent with the core definition of compassion as designated universally by spiritual traditions. The components that may only exist at different levels of compassion emotion. This could be developed separately from a neuroimaging task for later incorporation into the first-person based neuroscience methodology described previously.

Conclusion

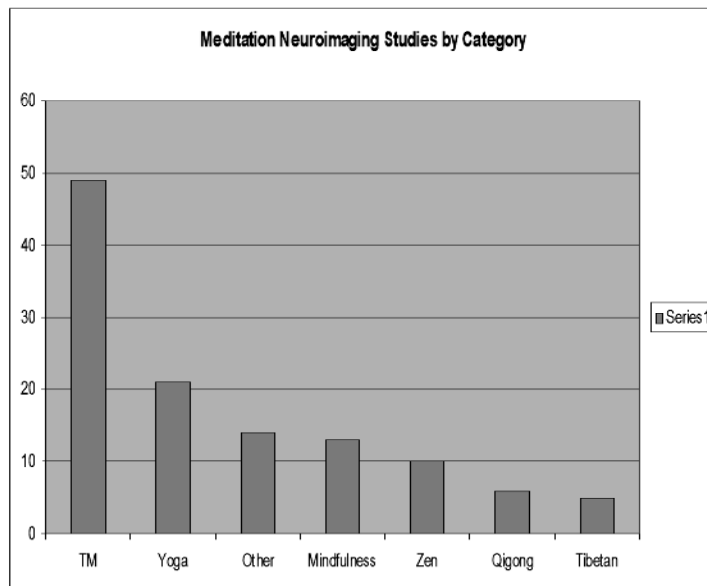
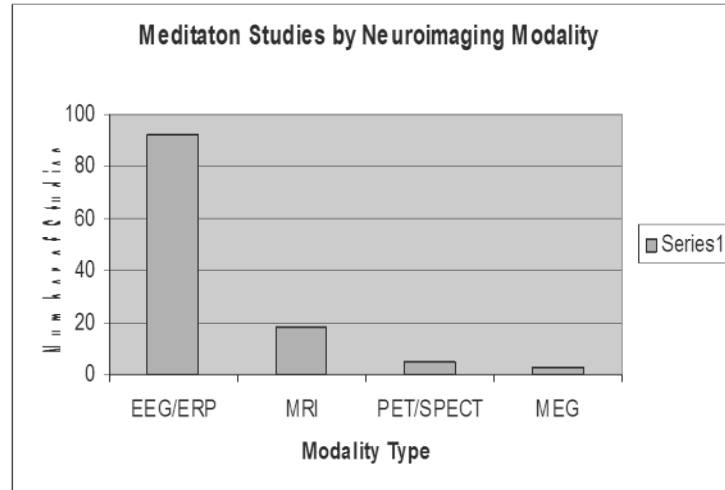
The findings in the present study predominantly support the use of scales with purported sensitivity to spiritual traits, and the use of MEG for obtaining the brain correlates of induced compassion state. The later finding while limited by the small sample size and high amount of variability in the MEG recordings provides justification for further investigation. The finding of the two highest level Roshis showing the largest activation response in the left fronto-temporal region in parallel with a unique activation of the right fronto-temporal region is intriguing. The findings were consistent with the broader empathy literature implicating anterior insula and amygdala activations, although further source space analysis would be required to more definitively determine the generator mechanism.

The study also demonstrates the utility of using brief “online” neuroimaging psychometrics to introspectively capture the conscious state of the subject immediately

after exposure to a controlled emotional stimulus. The pairing of the neuroimaging MEG task with self-rated conscious experience hence accomplished the goal of creating a first person neuroscience approach to the study of compassion. The refinement of the current methodology by using more task repetitions, combined with an increase in the sample size holds the promise of elucidating the neurophysiological correlates of spiritually-based compassion ability. The findings from future investigations on individuals embodying high level compassionate traits may one day help us understand how to help those with deficits in this ability, such as those with personality disorders or autism.

APPENDIX A

MEDITATION STUDIES BETWEEN 1947 AND 2010



APPENDIX B

EXPERIMENTAL COMPASSION QUESTIONS

Compassion Trait Measures (Embedded among unrelated questions)

Answered: 0=Not at all, 1=A little bit, 2=Somewhat, 3=Quite a bit, 4=Very much

10. I would not feel sad knowing a sadistic child murderer was slowly dying of cancer
11. I experience anger when I think of the person or people who have hurt me the most in my life
12. If I could absorb the suffering of a convicted killer being executed I would do so
14. I believe in standing up for myself even if another person's feelings may be hurt
18. I am not emotionally prepared to do volunteer work in a child terminal cancer ward
19. I deeply feel the sadness of other people
20. I would give my own life if I knew the lives of two strangers could be saved
21. Seeing another's person's happiness makes me happy even when I'm feeling down
25. I have so much going on that I am unable to worry about other people's problems
26. I become defensive when I hear someone insulting another person
27. I donate my time to community or institutional service work
29. I try to avoid people who are suffering
31. I try to remove insects from my home without killing them
34. I am not saddened by using traps to kill mice invading my house
36. I try to get back at people who have hurt me.
37. I wish to protect all beings from suffering
41. I am deeply moved when I see others suffering
44. I feel for a person I see with a disability
45. I would feel more sorrow for a person who was torturing me than I would for myself
46. If I could spare a stranger from being brutally tortured by volunteering to take their place I would do so
47. I experience discomfort when I am around people who are in pain
49. I would forgive a person who brutally murders my family or a close friend
51. I cherish others as much as I cherish myself
52. I would still wish for a person who killed my best friend to have happiness
53. People who leach off of society do not deserve help
54. I will avoid comforting a stranger I see in pain

- 55. I am uncomfortable being around a person who is suffering from a terminal illness
- 56. Given the choice I would rather someone else have the duty of telling a person their close loved one had died
- 57. I hate individuals who have tried to exterminate an entire race of people
- 59. Seeing a stranger in pain evokes the same intensity of feeling as if they were my closest relative or friend
- 63. On a weekly basis I experience emotional pain for people who are starving in other countries
- 70. I am uncomfortable visiting rest homes for the elderly
- 71. All living beings are equally important
- 72. I am unaffected by seeing a funeral of someone I do not know
- 73. I give as much as I can to legitimate charitable causes
- 75. I do not experience anger towards people who deliberately harm me
- 76. I will go out of my way to show a homeless person kindness and understanding
- 78. I would experience the same level of emotional response while watching a person beat a child as I would if they were beating a dog
- 79. I have a hard time knowing what to do when I see a person suffering

APPENDIX C

MEG TASK INSTRUCTIONS AND SCALES

INSTRUCTIONS

On the next screen you will be shown a picture taken of an actual person. The picture was taken moments after a young girl was removed from the car she was riding in during which both of her parents were shot to death in front of her by machine gun fire when they mistakenly failed to stop at a check point within a war zone. Although splattered with her parent's blood she was not physically hurt during the incident.

Since this event happened the child has continued to have nightmares nearly every night and is tormented by flash backs of the experience daily.

>When her picture appears please keep your eyes focused on her and **TRY YOUR BEST TO CONTINUOUSLY GENERATE AN INTENSE FEELING OF COMPASSION FOR HER.**

Please continue looking at the picture of the girl however now think of the girl in the picture as an actor who posed for the picture as part of a play, and the entire story about what happened to her as actually being totally fake.

>When her picture appears please keep your eyes focused on her **AND ALLOW YOURSELF TO EXPERIENCE WHATEVER FEELINGS MAY ARISE TOWARDS HER.**

Remember to keep your feelings focused on her.
(say “ready” to begin)

Please take your time and reflect carefully on the extent to which you experienced the feelings or states listed below in response to the picture you just observed. Please answer out loud by stating the word followed by a 0-8 number. There is no time limit for answering these questions so please take as much time as you need.

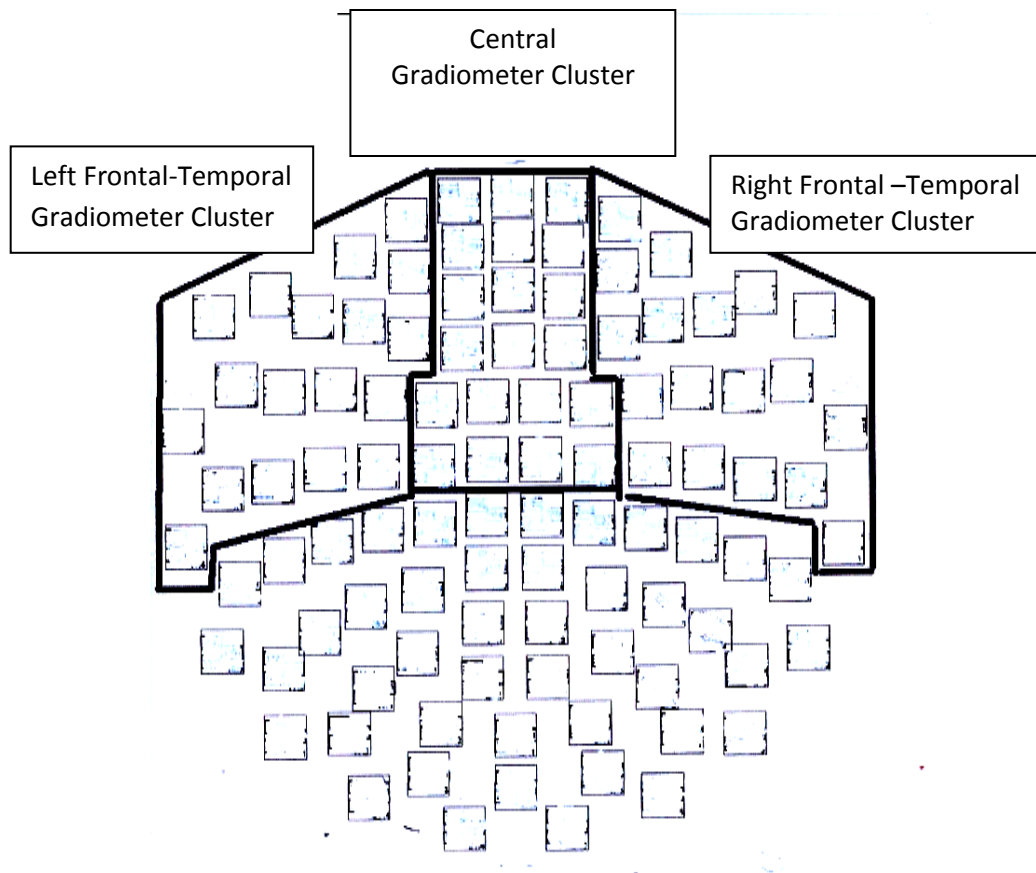
0 1 2 3 4 5 6 7 8

No feeling → Very Extreme or Powerful Feeling

Sadness
Love
Upset
Hostility
Distant
Fear
Forgiveness
Anger
Acceptance
Calm
Spite
Joy
Pity

APPENDIX D

MEG GRADIOMETER CLUSTERS



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